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This Test Operating Procedure (TOP) provides background information on the problems and adaptations associated with instrumentation, photographic, and video equipment required for conducting tests in cold regions. Basic information and procedures are presented as general guidelines to planning and using instrumentation systems for cold environments.

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

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DTIC AD No.

COLD REGIONS: INSTRUMENTATION OPERATION AND USE

*This TOP supersedes TOP 1-1-004, dated 1 May 1984.

1. SCOPE.

This document provides background information on the operation and adaptations associated with instrumentation, photographic, and video equipment required for conducting tests in a cold environment, both natural and simulated. Basic information and procedures are presented as general guidelines to planning and using instrumentation systems for cold environments.

2. BASIC INFORMATION.

The mission of the US Army Cold Regions Test Center is to test Army materiel for its ability to perform under cold regions environmental conditions. Instrumentation systems are required to define test conditions and to determine performance levels achieved in developmental equipment. Since many instrumentation systems are not designed to function at the low temperatures commonly found in cold regions, high altitudes, mid-latitude winters, and the simulated environment in a cold chamber, specific techniques and procedures are required for instrumentation to operate reliably and accurately in these environments. Cold temperatures will have a similar effect on instrumentation whether it is embedded in the equipment under test or a stand alone system. Further information regarding cold temperature effects is contained in Army Material Command Pamphlet (AMCP) 706-116[1**] and AMCP 706-118[2].

3. GENERAL ENVIRONMENTAL EFFECTS.

3.1 Low Temperatures.

Most materials become more brittle at low temperatures, thereby reducing their resistance to shock loading. Also, the differences in the coefficients of expansion affect all fits between dissimilar materials. At low temperatures, most rubbers, both natural and synthetic, lose their characteristic flexibility as do most plastics. Silicone products maintain flexibility at low temperatures but lack the strength of standard rubber items. Isolation and vibration absorbers easily fail if not selected to withstand cold temperatures. Some materials, such as glass, are extremely sensitive to thermal shocks so precautions should be taken to avoid rapid increases or decreases in temperature. Lubricants and fluids will increase in viscosity and may actually appear solid at extreme low temperature. In general, synthetic fluids and lubricants are less affected by cold temperatures than petroleum-based fluids and lubricants. Chemical reactions may be significantly slowed at low temperatures affecting photographic processes and chemical analysis measurements.

3.2 Snow and Wind.

Snow accumulations on the ground cause special problems. A warm object placed in snow may cause melting and refreezing resulting in adherence of ice to the surface of the object. Strong winds can carry large amounts of snow in fine particles; care in storage and placement of instruments may be required to minimize drift formation and damage due to snow intrusion. In

[**] Superscript numbers correspond to those in Appendix A, References.

combination with cold temperatures, wind increases the possibility of damage to equipment because of vibration, or because the equipment is blown over. It is important to keep equipment securely tied down. Winds also cause items to cool more quickly. Heaters and insulation will have to be selected to accommodate the increased rate of cooling.

3.3 Condensation.

Transferring instrumentation from the cold, dry environment into warm sheltered areas may result in condensation forming on the cold items, both externally and internally. Small heated shelters will have high humidity inside because of tracked in snow that melts or the number of people in the shelter. Condensation that forms on instruments may cause corrosion and short circuits. Furthermore, if the equipment is not properly cleaned and dried afterwards, returning it to the cold environment may cause damage to mechanical parts or electrical components. If instruments must be brought indoors, damage may be prevented by placing the equipment or instrumentation inside an airtight container (such as a plastic bag) before it is brought into a heated area. Once the instrument has reached the ambient indoor temperature, it can be removed from the container without damage. Instrumentation that is left out in the cold over days, weeks, or months can be subject to gradual moisture infiltration from even the smallest air leak. Extra precautions must be taken to ensure an airtight seal under these conditions.

3.4 High Latitude.

Daylight hours are greatly reduced during winter at higher latitudes. Working in the dark can be difficult. Additional task lighting may need to be provided. Personnel should carry a headlamp for hands-free illumination of work areas. The short daylight hours and low sun angle greatly reduce the effectiveness of solar panels. This, combined with frost buildup or snow cover, can render solar panels useless.

4. EQUIPMENT SAFEGUARDS.

4.1 General.

Since many pieces of equipment are incapable of functioning at extreme low temperatures, steps must be taken to ensure that instruments are operated in environments in which they are designed to function. This can be accomplished by building heated structures at stationary sites to house the equipment and operators. Heated vans can be modified to contain most of the test equipment and can be driven to test sites as required. Electrically powered enclosures or chemical heat packs can also be used to protect instrumentation. Development of solutions to meet test requirements necessitates a thorough knowledge of the instruments and equipment used as well as a thorough understanding of the effects of cold on the components. Operators of instrumentation in a cold environment should recognize the general hazards that can be encountered and the precautions which must be taken to prevent damage to the equipment.

4.2 Cables and Connectors.

Even though properly selected and of materials suitable for cold conditions, cables and connectors are more susceptible to damage if overly flexed or strained, and radios or microwave telemetry systems might be considered as replacements in appropriate situations. Cold-soaked cables which are rolled should be straightened only after being sufficiently warmed. To avoid breakage when retrieving cables, coil them in large loose coils. In some instances, e.g. if cables are frozen to the ground, it may be necessary to wait until temperatures warm before the cables can be retrieved. Electrical connections are susceptible to damage. Restraints must be chosen which transmit tensile load away from the connection. Since most parts become more brittle as the temperature drops, generous safety factors must be used in designing for strength, especially when impact loads are to be expected. Due to the high susceptibility of cables to damage, connectors, miscellaneous supports, and other spare items must be maintained at the test site. Design of the system must allow for rapid disassembly and assembly of these items to enable quick replacement if a failure occurs.

4.3 Batteries.

a. Because chemical reactions proceed more slowly at cold temperatures, cold batteries produce less current and, depending on the power draw, may not be adequate to power instrumentation. Discharged batteries are also more susceptible to freezing and possible damage to the case or internal components. It is important to keep batteries warm during and prior to use. Small batteries can be carried close to the body inside clothing utilizing body heat to maintain a functional temperature. During operation, insulated containers with heat packs/ hand warmers can be used to keep batteries warm. Ni-Cad, Ni-MH, or especially lithium-ion batteries generally outperform other battery types in the cold and should be considered, if available. Under some conditions, adapting the instrument to use external power connections may be required.

b. For all batteries, to obtain full power, warm a cold-soaked battery at room temperature (approximately 20°C) for several hours before charging or use. NEVER attempt to charge a frozen battery. At lower temperatures it will not accept a full charge and may freeze or explode. A frozen battery should be thawed by bringing it into a heated area (e.g. a heated shop) and allowing it to thaw completely prior to charging. A frozen battery may take as little as eight hours or as long as several days to fully thaw. More information on batteries can be found in File Manual (FM) 9-207[3].

c. Lead-acid batteries include wet-cell, gel cell, and AGM (Absorbed Glass Mat). Like all batteries, these are sensitive to cold and output voltage and available energy are reduced at low operating temperatures. Wet-cell batteries are not recommended for field use in a cold environment. If wet cell batteries have to be used, precautions must be taken to prevent freeze-up at low states of charge. Following are general guidelines for maintaining wet cell batteries in cold temperatures:

(1) Keep batteries fully charged. (Minimum of 1.250 specific gravity at 75% charge for lead acid storage batteries.)

(2) Keep electrical connections tight, clean and free of moisture or corrosion.

(3) Check water level often and add only when battery electrolyte temperature is above freezing. If water is added to a battery whose temperature is below freezing, it will not mix properly with the acid and may freeze.

(4) Never add acid to a battery electrolyte. It may explode or splatter acid and cause injury.

4.4 Still Imaging Equipment.

a. Digital photographic equipment is highly recommended in cold environments. It is more reliable and avoids the problems specifically associated with film. However, it may introduce new issues as digital displays may not operate and recording to digital storage media may be slower in cold temperatures. Equipment Safeguards (Paragraph 4 above) and the manufacturer's recommendations should be followed. The following guidelines are also provided:

(1) Most methods of achieving consistent reliable still images in the cold are based on common sense by protecting the equipment from the cold and keeping operations as simple as possible.

(2) Lenses or other auxiliary equipment should be treated in the same manner as cameras. To minimize the possibility of frost on lenses, care must be taken not to breathe on or near the camera lens.

(3) For operation in temperature below equipment specifications, heated environmental enclosures will be required for reliable operation. If power is not available hand warmers or heat packs are effective for short term (several hours) protection.

(4) If camera power is provided by external batteries, try to keep the batteries warm (e.g. in an insulated container, heated with heat packs/hand warmers) and do not expose them to low temperatures. If provisions can be made for a remote battery pack, keep it in a warm place.

b. For older photographic film equipment, in addition to the above recommendations, the following must be considered.

(1) Well maintained film cameras, lubricated with clean silicone or molybdenum lubricants, can be expected to operate reliably in moderately low temperatures. Temporary expedients (i.e. placing cameras under the operator's cold weather clothing) are an effective

protection for film camera equipment, but care must be taken to avoid condensation (see Paragraph 3.3).

(2) Film starts to stiffen in extreme cold and, unless handled delicately, will crack. If not kept sufficiently warm, sprocket holes will tear out during operation, and the pieces could damage or scratch the remainder of the film.

(3) Static electricity can build up in the film and cause streaks as discharges take place. Use films with backings that help dissipate static electricity buildup to combat this.

(4) Film tends to lose speed (i.e., sensitivity to light will drop) as it gets cold. Color films may also exhibit a color shift as one emulsion layer slows down more than another.

c. The following considerations apply to both digital and film equipment.

(1) Low angle, bright sun and glare from snow increases inaccurate light meter readings. Therefore, use reflected light meters to take a reading of a gray card or similar target. Incident light meters are better because they measure the light at the scene and are not affected by reflections.

(2) Snow also affects picture quality by increasing the amount of ultraviolet light impinging on the camera lens. Color correction filters or their equivalent must be used to achieve normal color balance. Polarizer filters are also very effective in providing contrast in snow-covered terrain or haze.

(3) Cameras must not be positioned where they may be subject to vehicle exhaust, which will obscure the image.

(4) Condensation leading to freeze-up is a problem at cold temperatures, and causes most damage, but is simple to prevent. Equipment brought indoors from cold temperatures, if no preventive action is taken, will be subjected to condensation in/on the camera. The condensed water may also freeze if not allowed to dry out prior to being taken out-of-doors. To prevent this, leave equipment in moderate cold (below freezing) areas. If possible, prior to reentering a building, place the equipment in an airtight desiccated case. Do not remove it until it reaches the indoor temperature or it is moved out of doors again.

4.5 Video Equipment.

Digital recording and storage solutions are more suitable for cold environments with the considerations noted in paragraph 4.4. Video cameras and recorders are susceptible to the same problems as still film and motion picture cameras. Some of these problems are not as easy to correct, e.g. tapes stiffen and will not track properly in the extreme cold. Operation of video tape recorders should not be attempted in the cold without heated environmental enclosures or shelters

4.6 Computers, Digital Displays.

Some display and computer screens may be slow reacting or not work at all in a cold environment. This will also occur in digital displays that are part of embedded instrumentation in current Army equipment being operated or tested in a cold environment. Manufacturer's specifications as to the temperature limitations must be known and followed, where possible. If these limitations will be exceeded, a heat source must be used to warm the display and equipment.

5. ACCURACY OF DATA.

5.1 Instrument accuracy may be degraded if operated below the manufacturer's temperature specification. Instrumentation equipment may not only be damaged or rendered inoperable due to the effects of the cold environment, but a seemingly functional system might be so affected by cold as to produce data outputs which are inaccurate. Knowledge of the parameters to be measured during test is essential and recognition of and allowance for reduced accuracies should be made. Whenever possible, provision should be made for test equipment to be operated in the temperature ranges specified by the manufacturer.

5.2 Mechanical linkages and interfaces can become stiff, causing errors or long response time. Spring-type scales may be affected due to coefficient of expansion and other physical changes in the material. Gauge response times and values of readings may be affected due to the changes of viscosity, differences in the coefficient of expansion, and increased brittleness and stiffness.

5.3 Since all instrumentation may yield less accurate data when operated in a cold environment, an instrument should be operated or checked out in the most severe condition in which it must operate. If instrumentation is not designed or calibrated for cold environment operation, it should be operated in a cold chamber prior to use in the field. This check will show the temperature dependence and reliability of the data obtained and ensures proper functioning of the system at expected operating temperatures. When the data is submitted it should be noted whenever the temperature range of a calibrated item has been exceeded.

6. HUMAN FACTORS CONSIDERATIONS.

6.1 An important consideration for operating instrumentation in the cold is the compatibility of the system with operators. All manipulations are complicated by the cold environment. For man to survive at extreme low temperatures suitable cold weather clothing is required. This heavy clothing restricts movement and decreases dexterity. Most knobs, switches, and levers are too delicate to be operated while wearing heavy cold weather mittens or gloves. Operators must wear thinner contact gloves for fine adjustments while taking care to expose hands for the least time necessary to complete the task while avoiding cold exposure that may cause frostbite.

6.2 Manual collection of data is difficult. Notes written while wearing large mittens are often illegible and the possibility of frostbite exists if the volume and time required is too great for

wearing thinner, more flexible gloves with less insulation. To minimize the quantity of data which must be read in the field, preprinted collection forms may be developed to reduce the job to a fill-in-the-blanks operation. It is highly desirable to use digital systems to reduce the complexity of operations that must be performed by the individual in the cold. However, as discussed above, these also require protection from the cold.

6.3 Early planning is necessary to build efficiency into the data collection effort early on to minimize wasted effort and the difficulties encountered when operating in a cold environment. The extreme cold can affect the attitude and morale of the individual working in the environment. This adverse effect must be considered when developing the instrumentation system and planning the test and data collection effort. As the duration and complexity of the operations performed in the cold increases, the operator may attempt to shorten procedures disregarding the equipment or the quality of data being gathered. While these problems may be reduced by ensuring individuals are well trained in cold weather operations, even the best trained and well motivated individuals may be affected when they get cold. It is important for the test director and the technical support staff to plan carefully together, to reduce last minute changes, and be constantly aware of the condition of personnel as they conduct testing in the cold. A well organized and well planned data collection effort will focus on the data required, at the accuracy required to support the analysis of performance objectives. Additional guidance is provided by Military Standard (MIL-STD) 1472 F[4].

7. SUMMARY

In general, almost any piece of equipment can be made to work in the cold by individuals who are familiar with cold regions' conditions although procedures may differ from those used in warmer climates. Conversely, any piece of equipment may malfunction in the cold if special precautions are not taken. Personnel knowledgeable and experienced in cold weather effects on instrumentation can be invaluable to the success of a test in the cold environment.

APPENDIX A. REFERENCES

1. AMCP 706-116, Engineering Design Handbook, Environmental Series, Part Two, Natural Environmental Factors, April 1975, DTIC Accession Number ADA012648.

2. AMCP 706-118, Engineering Design Handbook, Environmental Series, Part Four, Life Cycle Environments, April 1975, DTIC Accession Number ADA015179.

3. FM 9 -207, Operation and Maintenance of Ordnance Materiel in Cold Weather (0° to -65°F), 1998

4. MIL-STD-1472 F (1), Human Engineering, 5 December 2003.

Recommended changes to this publication should be forwarded to Commander, U.S. Army Developmental Test Command, ATTN: CSTE-DTC-CT-T, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: U.S. Army Cold Regions Test Center, ATTN: CSTE-DTC-TP-CR-CO, PO Box 665, Delta Junction, AK 99737. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22304-6145. This document is identified by the accession number (AD No.) printed on the first page.